A SYNOPTIC ANALYSIS OF TIROS II RADIATION DATA OVER NEW ZEALAND AT NIGHT

30p.

[redacted]

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Infrared radiation measurements in the 8-12 micron, 8.0-30 micron and 6.0-5.6 micron wavelengths from TIROS II on its initial orbit over New Zealand are examined in detail. A subjective analysis of the synoptic situation confirmed the fact that the TIROS II radiation data clearly outlined two broad scale frontal systems in the Tasman Sea at night. The equivalent blackbody temperatures measured in the 8-12 micron region were found to be 6 to 12 degrees Kelvin colder than the sea water temperatures in warm radiation source areas. In the 6.0-6.5 micron region, the equivalent blackbody temperatures, when converted to "effective radiation height" averaged 8705 feet below the tropopause at five upper air stations.

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INTRODUCTION

The TIROS II (1960 Pi I) meteorological satellite, that provided the data for this analysis, was launched from Cape Canaveral, Florida, on November 23, 1960. The satellite was spin-stabilized and space-oriented in a near circular (454.4 statute-mile apogee, 385.6 statute-mile perigee) orbit with a period of 98.3 minutes. TIROS II was the first satellite to be equipped with a five-channel scanning radiometer to measure reflected solar radiation and infrared emission from the earth and its atmosphere, in addition to the two-television-camera system.

 [redacted]

The radiation data selected for this analysis were obtained during Orbit 0 of TIROS II, as the satellite initially viewed the New Zealand area. This study is an attempt to use the radiation data to delineate night-time cloud cover in a remote "sparse data" oceanic area.

A brief description of the scanning radiometer and its regions of spectral sensitivity precedes the subjective synoptic analysis of the storm area. A comparison of frontal clouds with satellite radiation patterns and a preliminary tropopause height relationship with Channel 1 radiation data are presented.

THE SCANNING RADIOMETER

The scanning radiometer is a five-channel instrument that provides measurements of the terrestrial and reflected solar radiation in selected regions of the infrared spectrum (Figure 1).

The five spectral regions and their characteristic functions are[1]:

Channel 1: 6.0-6.5 microns - water vapor absorption
Channel 2: 8-12 microns - atmospheric window
Channel 3: 0.2-6 microns - reflected solar radiation
Channel 4: 8-30 microns - thermal radiation from the earth and atmosphere
Channel 5: 0.55-0.75 microns - visible reference and daytime cloud cover

The approximate transmission characteristics of the three long-wave channels (1, 2, and 4) are shown in Figure 2.

The radiometer detects the radiation energy flux viewed during a scan by means of an optical system designed to chop and apply the radiation to five thermistor detectors. A filter system is employed to separate the five spectral regions.

The radiometer has a five degree by five degree view angle which results in a field of view encompassing approximately 40 x 40 statute miles on the earth when the sensor nadir angle is zero. An increase in nadir angle results in an elongation of the field of view in the viewed direction. The optical axes of the five channels are parallel to one another and inclined to the satellite spin axis by 45^{o}. Three earth scanning modes or patterns of the radiometer, as shown in Figure 3, may be described as follows:[2]

(a) Closed Mode: All scan spots throughout a number of spin cycles of the satellite are earth-viewed, either through the "wall" (side) sensor or the "floor" (baseplate) sensor.

(b) Single Open Mode: Some scan spots of a spin cycle are space viewed and the remainder are earth viewed through the wall sensor only or through the floor sensor only.

(c) Alternating Open Mode: The scan spots of a spin cycle are a combination of space and earth viewed, alternately through the wall sensor and the floor sensor.

The rotation of the satellite (8-12 rpm) provides the radiometer with a scan sweep that alternately views outer space (near zero radiation) and the earth's surface. The sensors measure the difference in energy flux over the scanned field of view. The output of the sensor is recorded and transmitted to the ground stations where it is converted electronically into usable form. A detailed description of the data handling and conversion process is given in Reference 3.

The output of the radiometers can be described in terms of either equivalent blackbody temperatures (degrees Kelvin) or watts per square meter of radiant emittance within the spectral response curve of each channel (Figure 4.)[4] The relative accuracies of Channels 1 and 2 were estimated to be plus or minus 2 degrees C, while the absolute values may vary by plus or minus 5 degrees C as a result of second order effects in the calibration procedure.[5]

Channel 2 primarily measures the radiation (8-12 microns) from the earth's surface if there are no clouds or from the tops of clouds, if they exist. The relationship between the cloud layers and the emitted infrared radiation has been expressed as follows: "An overcast of dense middle and high clouds whose tops are cold, emits relatively little energy. By contrast, nearby areas of lower clouds or broken clouds or cloudless areas emit more energy. If the radiating surface is opaque, the energy emitted by the surface and measured by the satellite is related to the temperature of the surface; otherwise, the radiation is a complicated function of cloud amount and structure".[6] A preliminary estimate of overcast cloud top heights can be made by relating the Channel 2 equivalent blackbody temperatures to nearby radiosonde temperature-height data.

Channel 4, which covers the 8-12 micron window region as well as the 12-30 micron region, is characterized by strong absorption bands of carbon dioxide and water vapor.

Channel 1 responds to radiative contributions, depending upon the water vapor, temperature, and pressure profiles, from a broad region in the middle and upper troposphere.

The radiation data for Channels 2, 4 and 1 (Figures 7, 8 and 9) were recorded during a seven minute period at approximately local midnight and were reduced to usable form with the aid of an electronic computer (IBM 7090).[4] The TIROS II satellite was spinning at 8.0 rpm at swath 1 (1223 GMT), 700 miles southeast of Australia. The camera nadir angle was 127 degrees at swath 1 and slowly changed to 159 degrees at swath 74 (1232 GMT). The swath (radiation viewing path) changed from a parabolic arc to a nearly circular sweep pattern during this period.

SYNOPTIC ANALYSIS AND COMPARISON WITH RADIATION DATA

Four independently analyzed surface charts for 1200 GMT, November 23, 1960, were requested and received from the New Zealand and Australian Meteorological Services, the Commander of the U.S. Naval Support Force in Antarctica, and from the International Antarctic Analysis Center, Melbourne, Australia, by courtesy of the U.S. Weather Bureau representative. A final composite synoptic chart and nephanlysis, (Figures 5 and 6),was analyzed and drawn from the above charts with the assistance of Lt. Comdr. John D. Ploetz, Wintering Over Officer 1960, U.S. Naval Weather Service, Washington, D. C.

The two cold-type surface meridional occlusions, shown in Figures 5 and 6 had moved east and southeast off the east coast of Australia and had intensified in the Tasman Sea, within the preceding 24 hours (November 22-23, 1960). A long northsouth band of low equivalent blackbody temperatures (cold radiation sources) in the Tasman Sea (Figures 7, 8 and 9): 240 to 258 degrees Kelvin, 233 to 255 degrees Kelvin, and 225 to 237 degrees Kelvin, for channels 2, 4, and 1 respectively, clearly outline these well-developed occluded fronts. The zip-toned shading delineates the areas of cooler equivalent blackbody temperatures. By relating the above Channel 2 temperatures to nearby radiosonde data, it was estimated that the dense high overcast cloud layers in the meridional occlusions extended to 5-7 kilometers.

Fritz and Winston[6] estimated the cloud tops over the United States during TIROS II Orbit 4 (daytime) by use of upper air constant pressure charts, radiosonde reports, and the conversion to height of Channel 2 equivalent blackbody temperatures. It was noted that the blackbody temperatures of thin less-opaque cirroform clouds over surface fronts related to the contributions of the cirroform clouds and the denser altoform and/or stratoform cloud layers below. Thus the presence of thin high cloud layers can only be deduced by an intelligent analysis of the synoptic situation and from climatological data.

Smaller cold radiation areas over the rugged mountain ranges of New Zealand indicate orographic - type clouds while larger cold radiation sources at 173 degrees E.Long. and 50 degrees S. Lat. indicate multilayered stratoform-type clouds typical of the west side of a maritime 1022 mb. surface high. Broad areas of warm equivalent blackbody temperatures: 265 to 282 degrees Kelvin, 261 to 273 degrees Kelvin, and 237 to 246 degrees Kelvin for channels 2, 4 and 1 occur over three surface high pressure regions. Warm radiation sources indicate areas that are: (1) cloudless, (2) covered by warm low clouds, or (3) covered by scattered or broken clouds over a warm surface.[6] The third weather condition best describes the synoptic cloud coverage over the weak surface maritime highs.

Based upon the subjective interpretation of the three well-correlated sets of radiation data, the warm front originally drawn south of New Zealand was redrawn as an upper warm front and the surface portion placed meridionally to the west of South Island, New Zealand, (Figure 7).

At 1200 GMT, November 23, 1960, surface air temperature and sea water temperature chart was drawn and analyzed, and a comparison made where the warmest Channel 2 equivalent temperatures (282 and 278 degrees Kelvin) occurred. (See Figure 10). At 168°E long. 42°S Lat., the Channel 2 equivalent temperatures were noted to be 6 to 10 degrees Kelvin colder than the sea water temperatures.

This difference was probably caused by the fact that some energy in Channel 2 is still received from water vapor and ozone in the atmosphere, i.e., this channel is not an entirely transparent "window".

The most complete upper air information for the 850 mb up through the 200 mb constant pressure levels was available at 0000 GMT, November 23 and 24, 1960. The 300 mb chart (Figure 11) 0000 GMT, 23 November 1960, was selected to show the strong circulation pattern which persisted from the 700 mb. to the 200 mb. level for the 24 hour period. A strong jet stream (140 kt maximum) is outlined by the 120 kt isotach along the 160 degree E meridian over Macquarie Island, approximately 5 degrees west of the surface front. A secondary 80 knot isotach maximum is shown northeast of North Island, New Zealand.

Aircraft weather reports (Figure 12)[7] which were plotted from 0013 GMT to 2330 GMT November 23, 1960 helped to verify the 1200 GMT surface synoptic analysis (Figure 5). Multiple layers of low clouds (stratoform and cumuloform, with bases from 3000 to 5000 feet and tops from 6000 to 8000 feet) middle clouds (altostratus-altocumulus, with bases from 8000 to 11,000 feet, and tops from 18,000 feet) and high clouds (cirrostratus with bases of 25,000 feet), and lines of thunderstorms (cumulonimbus with tops indicated at 28,000 feet by aircraft radar) were reported in the area of the front between zones 30 to 40 degrees S. Broken altostratus and cirrostratus cloud layers were reported by aircraft at 0612 and 0627 GMT in the Tasman Sea. These dense, opaque cloud decks, with tops 18000 to 25,000 feet are confirmed by the 240 to 258 degree K equivalent blackbody temperatures recorded 6 hours later by Channel 2 (Figure 7).

Pilot weather reports, with an assist from aircraft radar, were considered to be among the most valuable sources of cloud information at night over this remote maritime area.

Thus, the experienced meteorologist, through the judicial combination of TIROS II radiation data, aircraft weather reports, and all available surface charts and upper air information, can obtain a reasonably detailed nocturnal description of the horizontal and vertical cloud distribution in the stormy Tasman Sea.

TROPOPAUSE HEIGHT ESTIMATE

Widger and Touart[8] and House and Blankenship[9] have indicated that the Channel 1, 6.0-6.5 micron radiation data may be useful in estimating tropopause heights. Hanel and Wark[5] have shown that Channel 1 responds to water vapor emission in a broad region of the middle and upper troposphere with the maximum contributions emanating from the vicinity of 400 mb.

In order to verify this height estimate, Channel 1 equivalent blackbody temperatures over 5 radiosonde stations were converted to "effective radiating heights" by means of Figures 13 and 14 and analyzed in Figure 15. The effective "heights" were subtracted from the actual tropopause sounding heights at 0000Z on November 23, 1960 and averaged in Table I. The tropopause heights were determined in accordance with the WMO definitions in AWS Manual 105-124.[10] The base of a lower inversion at 36,350 ft. at Invercargill was used in Table 1, because it closely approximated the WMO definition for a conventional tropopause. The lower polar tropopause height (32,700 ft) was used at Auckland, which exhibited a multiple tropopause structure.

TABLE I

	Trop. Height			Channel I "Effective" Height			Height Diff.	Temp. Diff
Station	(feet)	(mb)	(°K)	feet	(mb)	T_{BB} (in °K)	(feet)	(°K)
Auckland	32,700	266	228°	27,280	340	237°	5,420	9°
Invercargill	36,350	230	218°	26,930	358	240°	9,420	22°
Campbell Is.	39,200	200	211°	30,980	295	230°	8,220	19°
Macquarie Is.	34,800	230	219°	22,350	405	242°	12,450	23°
Christchurch	33,850	257	221°	25,840	365	238°	8,010	17°
						Average:	8,705	18°

Table I indicates that the Channel 1 (6.0-6.5 micron) maximum integrated radiation level averaged 8705 feet below the tropopause and qualitatively confirms the work of Hanel and Wark. The T_{BB} for Channel 1 averaged $18^{o}K$ warmer than the tropopause temperatures, in this study.

W. R. Bandeen, Goddard Space Flight Center[11] suggested an empirical equation to obtain a closer tropopause height estimate from the Channel 1 data:

(1) Tropopause Height = 55,000 feet - $530^{(T_{BB}\ \text{Chan. } 1[^{o}K]-200)}$

A comparison of the tropopause height from the same radiosonde soundings with the estimated tropopause heights, by use of equation (1), is shown in Table II:

TABLE II

Station	Trop. Height (feet)	Est. Trop. Height (feet)	Height Difference (feet)	Tropopause Characteristics
Auckland	32,700	35,390	-2,690	multiple
Invercargill	36,350	33,800	-2,550	single
Campbell Is.	39,200	39,100	- 100	single
Macquarie Is.	34,800	32,740	-2,060	single
Christchurch	33,850	34,860	+1,010	single

Table II indicated that the estimated tropopause height ranged within +1010 to -2690 ft. at radiosonde stations with single and multiple tropopauses.

Defant and Taba[12], in their worldwide hemispheric investigation of tropopause heights and temperatures stated: "With the exception of the very northern latitudes (75^{o} to $90^{o}N$) , the close relationship between tropopause height and tropopause temperature seem to be almost perfectly fulfilled in the sense that an increase in height goes parallel with a decrease in temperature or vice versa (compensation principle)". One can presume that the same relationship holds for the southern hemisphere.

Since tropopause temperatures and heights are operational requirements for the stratosphere flights of military and civilian airline aircraft[13], more comprehensive studies of these parameters with TIROS radiation data will be made in the future.

CONCLUSION

The TIROS II radiation charts described in this study point to the meteorological potential of satellite radiation coverage as an important means of synoptic observation of frontal movement and interpretation of large scale atmospheric flow patterns.

ACKNOWLEDGEMENTS

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11. W. R. Bandeen - Private Correspondence, Sept. 1962
12. F. R. Defant and H. Taba, "The Threefold Structure of the Atmosphere and the Characteristics of the Tropopause", Tellus, Vol. 9, No. 3, August 1957, p. 259-274
13. D. L. Jones, D. S. Cooley, T. A. Carey, "A Survey of Observational Requirements from Meteorological Satellites 1963-1966", Travelers Research Center, Inc., July 1962

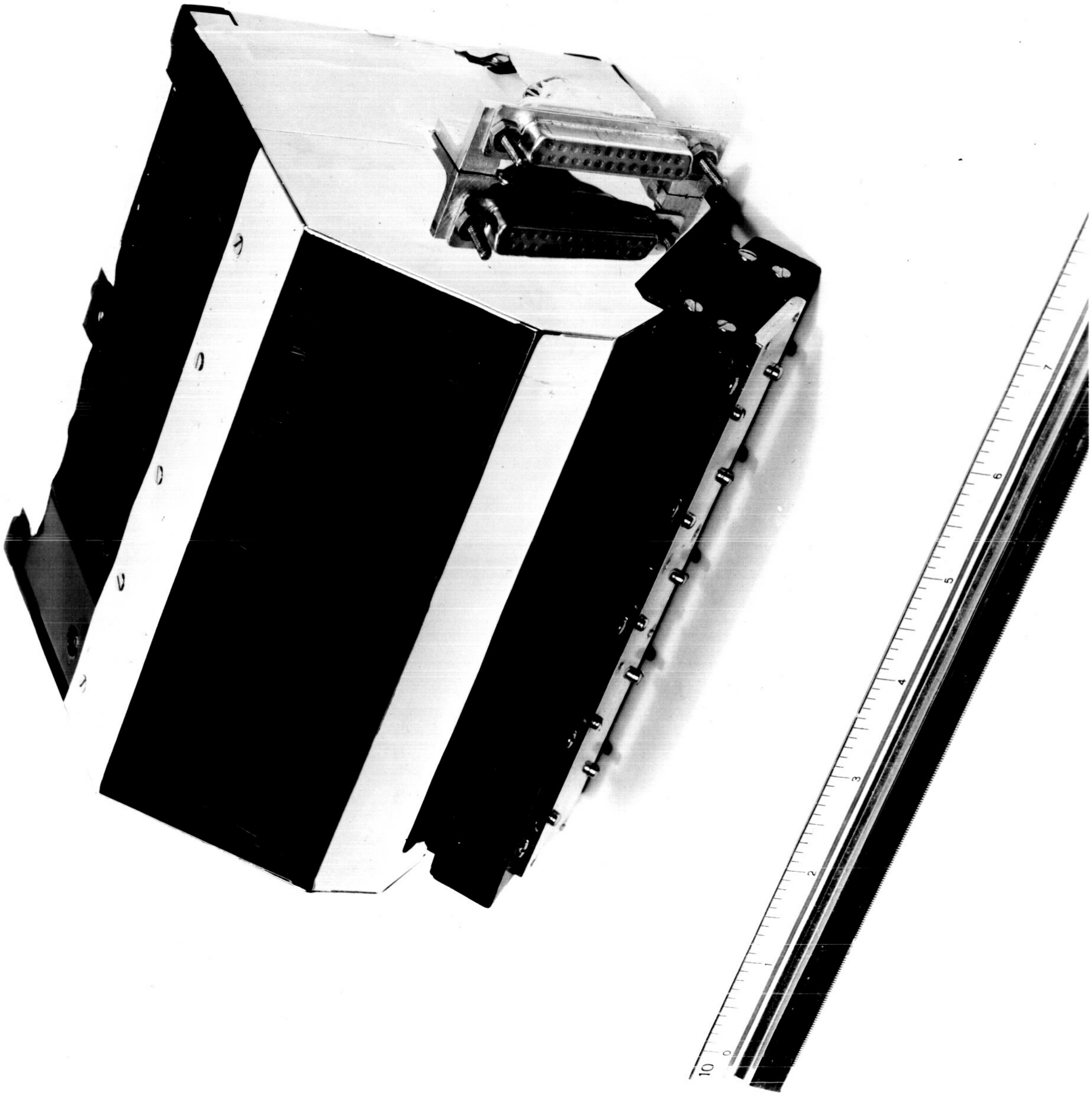
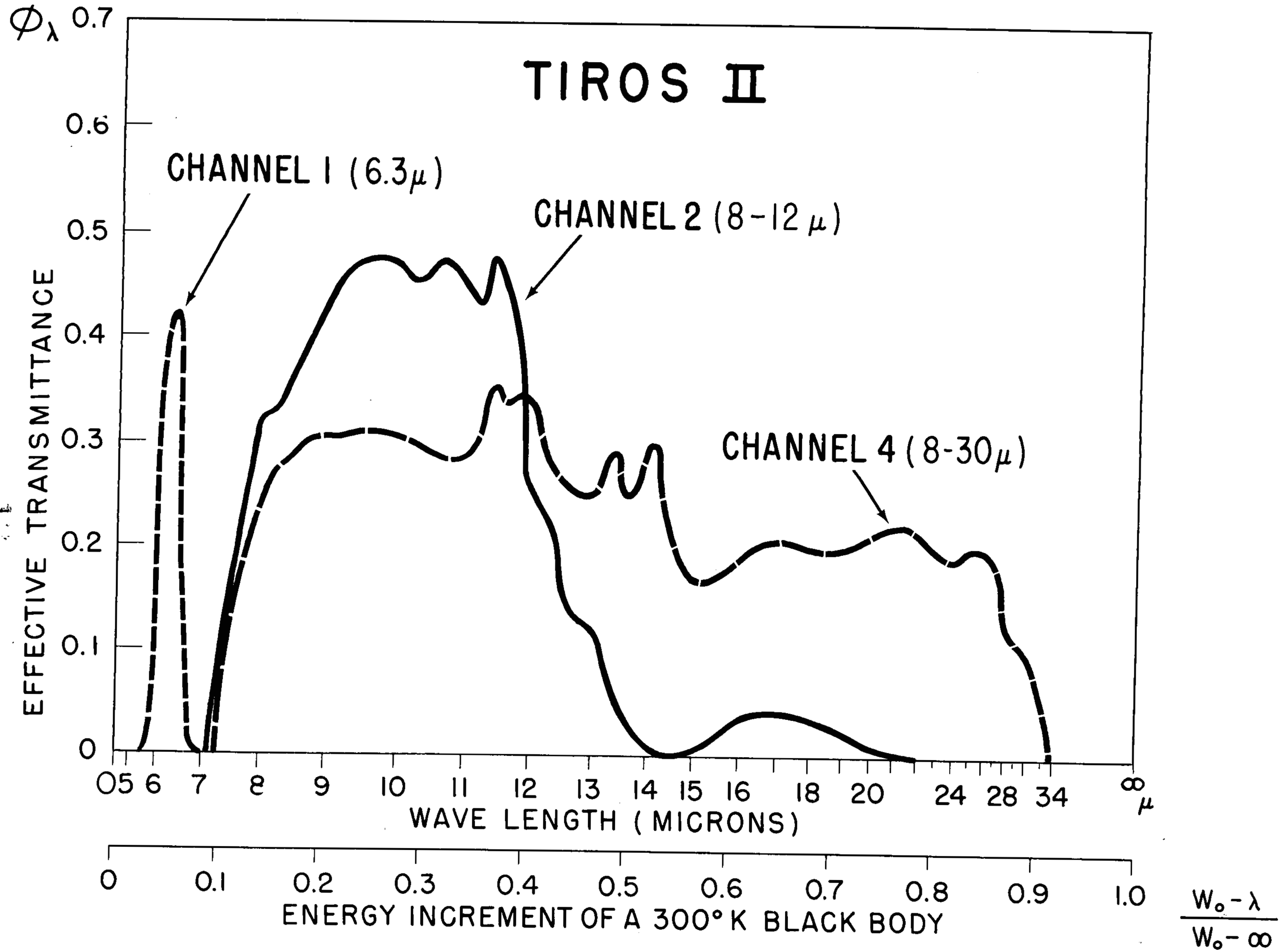


Figure 1 - External View of the 5-Channel Scanning Radiometer Showing the View Aperatures in one direction.



TIROS II
Φ_λ
EFFECTIVE TRANSMITTANCE
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CHANNEL 1 (6.3μ)
CHANNEL 2 (8-12 μ)
CHANNEL 4 (8-30μ)
05 6 7 8 9 10 11 12 13 14 15 16 18 20 24 28 34 ∞ μ
WAVE LENGTH (MICRONS)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
ENERGY INCREMENT OF A 300° K BLACK BODY
$\frac{W_o - \lambda}{W_o - \infty}$

Figure 2 - Spectral Response (ϕ_{λ}) Characteristics of Channels 1, 2, and 4 of the 5-Channel Scanning Radiometer.

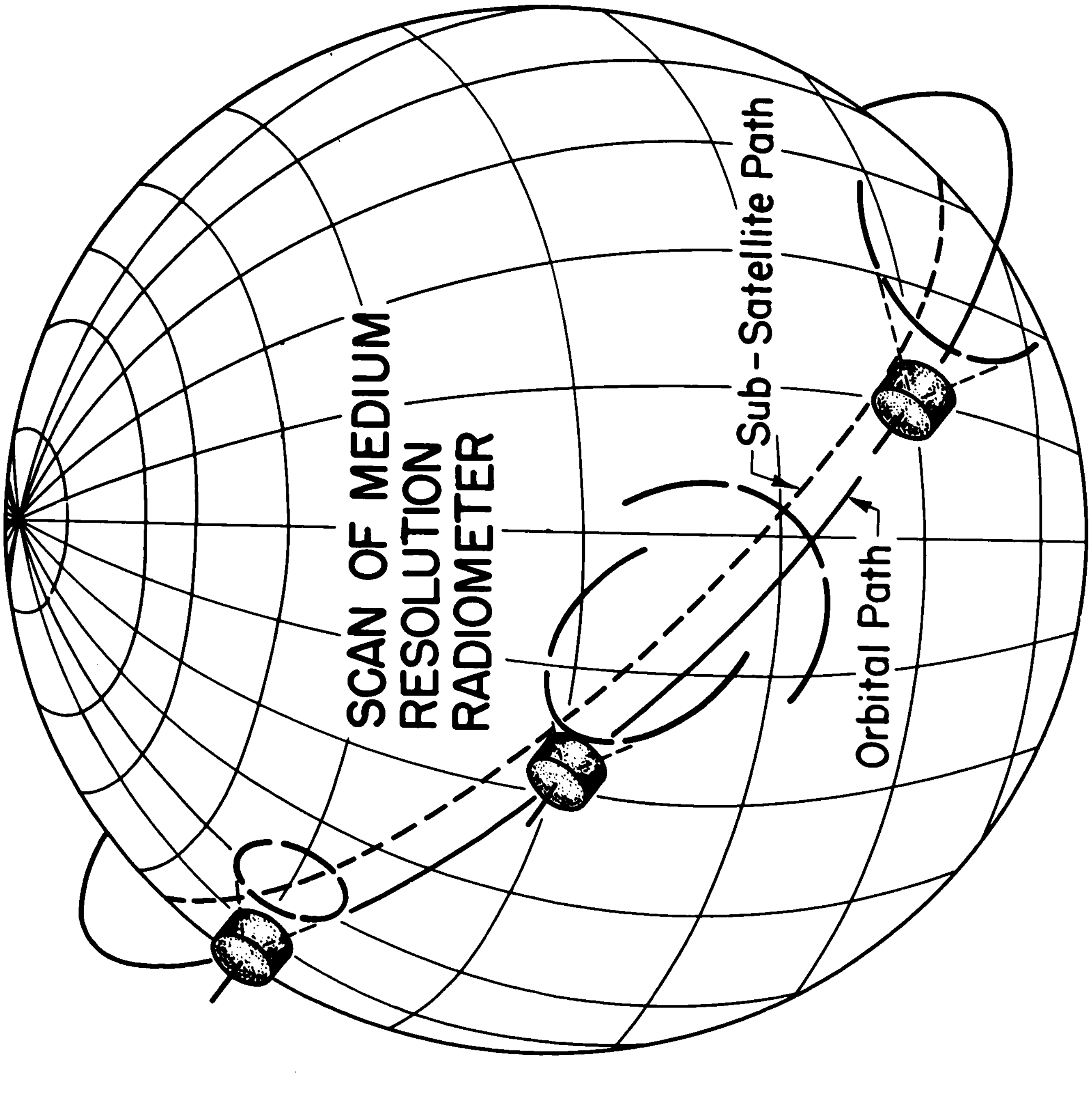

SCAN OF MEDIUM
RESOLUTION
RADIOMETER
Sub-Satellite Path
Orbital Path

Figure 3 - The Scan Patterns of the TIROS II 5-Channel Scanning Radiometer. (The closed, single open and alternating open modes are illustrated from left to right.)

TIROS II SCANNING RADIOMETER

CHANNEL 2 (106A)

($8-12\mu$)

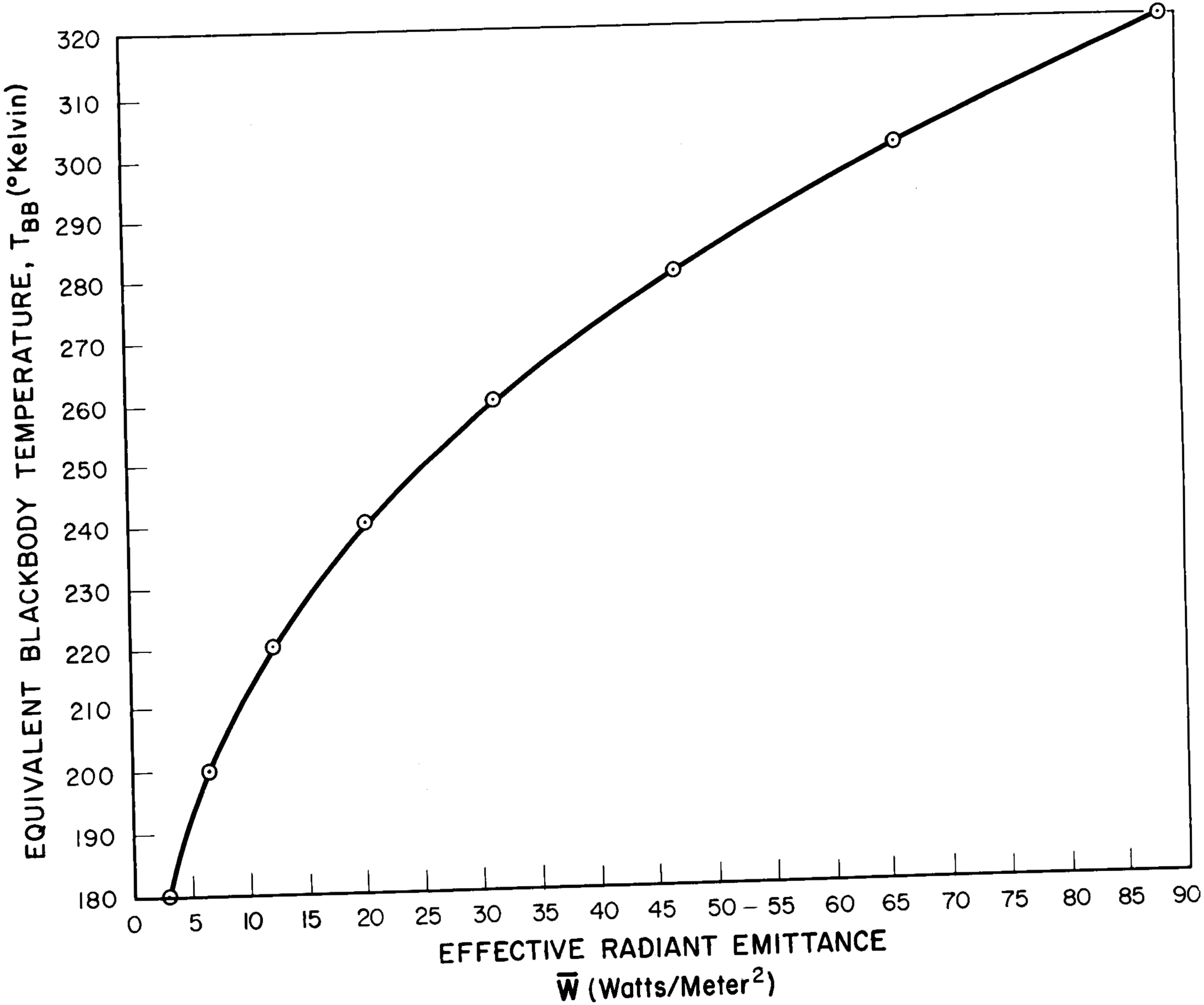
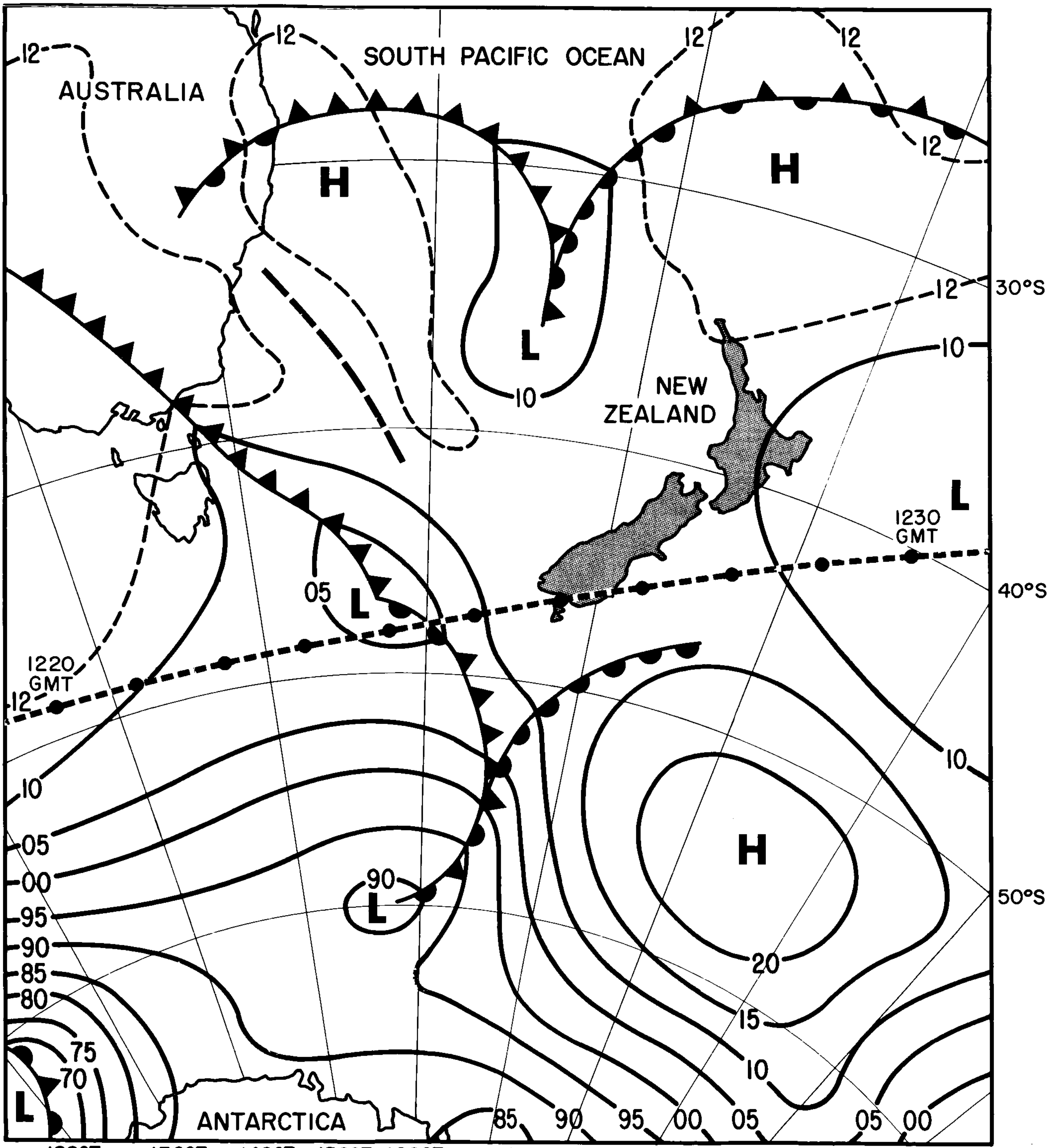
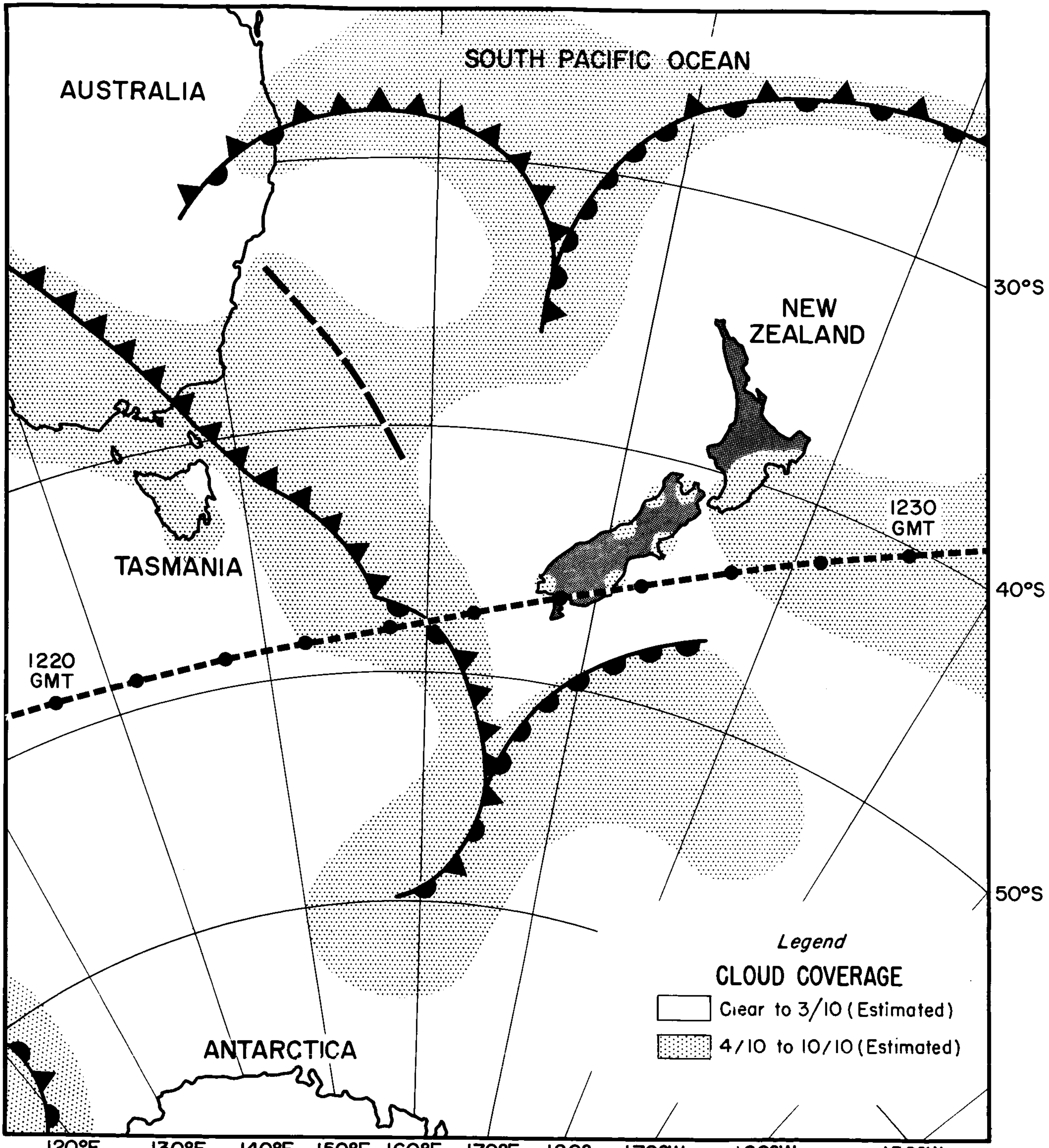


Figure 4 - Equivalent Blackbody Temperature versus Effective Radiant Emittance for Channel 2 of the TIROS II Scanning Radiometer.



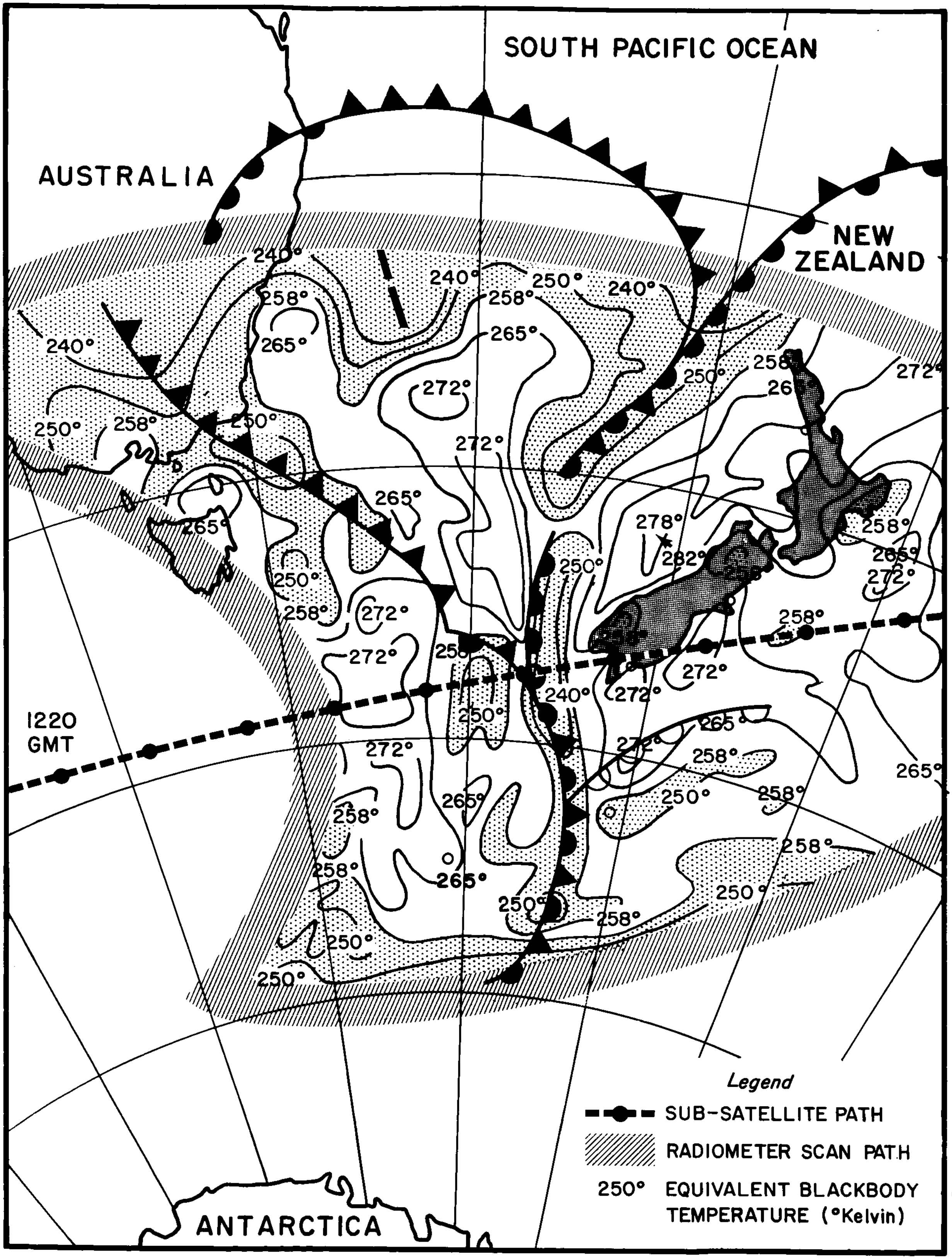
POLAR STEREOGRAPHIC PROJECTION

Figure 5 - Surface Synoptic Chart for the New Zealand Area, Showing Sea-Level Isobars and Fronts, 1200 GMT, 23 November 1960. Satellite Track during Orbit 0 is shown by a Heavy Dashed Line, with a Dot Indicating every Minute of Time.



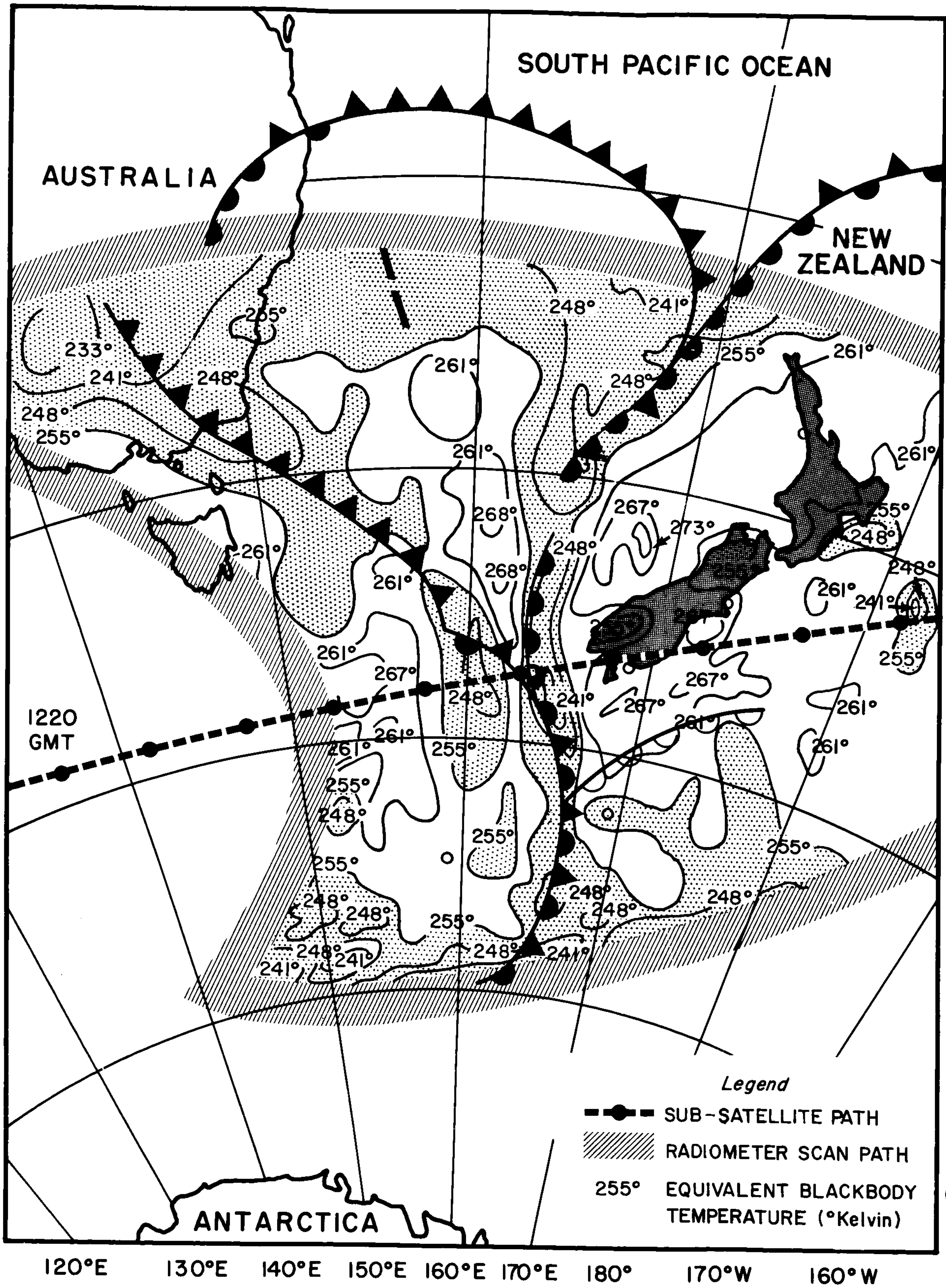
POLAR STEREOGRAPHIC PROJECTION

Figure 6 Nephanalysis of the Surface Synoptic Chart 1200 GMT, 23 November 1960 - TIROS II, Orbit 0.



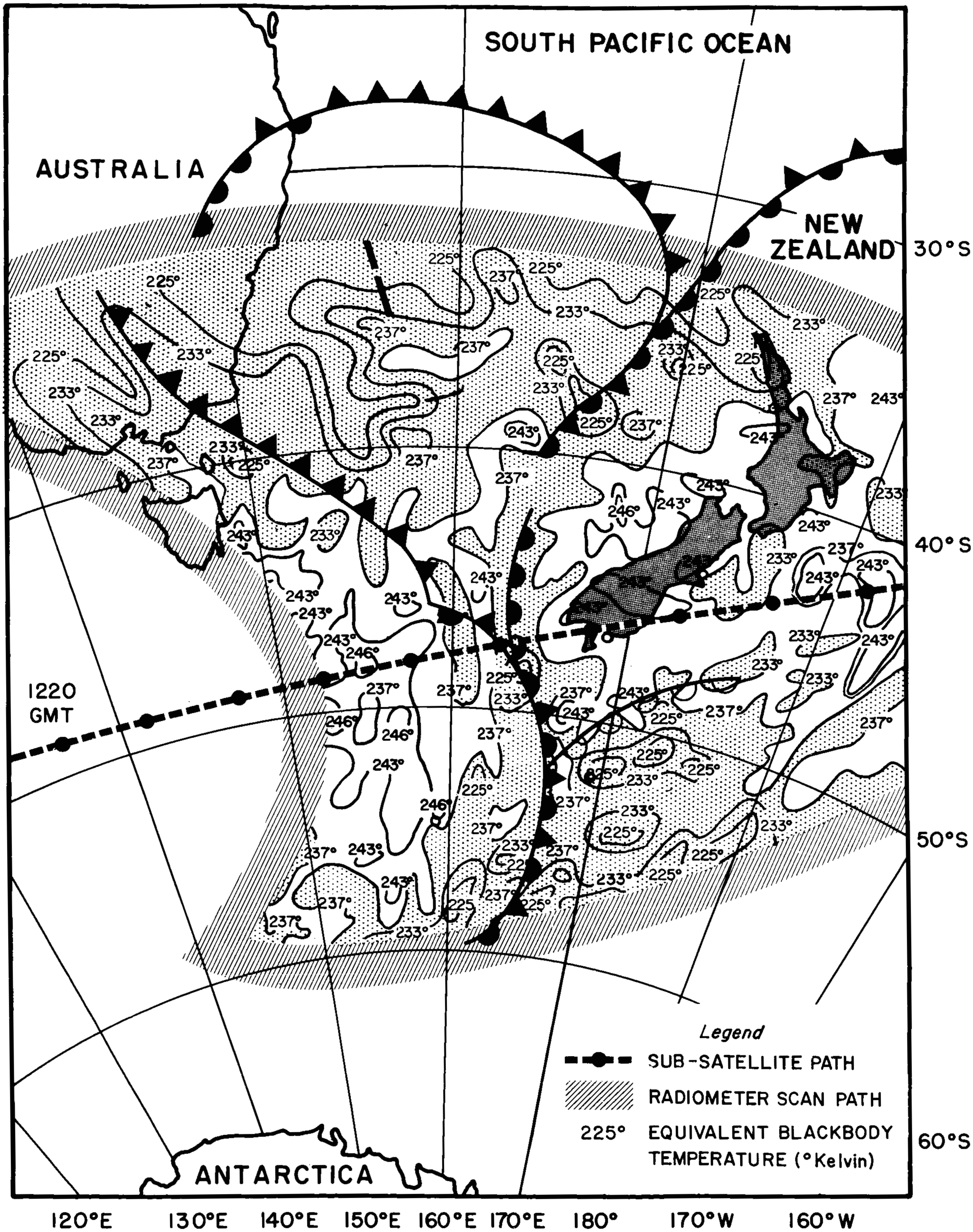
POLAR STEREOGRAPHIC PROJECTION

Figure 7 - Radiation Map from the TIROS II 5-Channel Scanning Radiometer; Channel 2, Orbit 0, 23 November 1960, 1220-1230 GMT, Orbit 0. (New Zealand was zip-toned for orientation purposes)



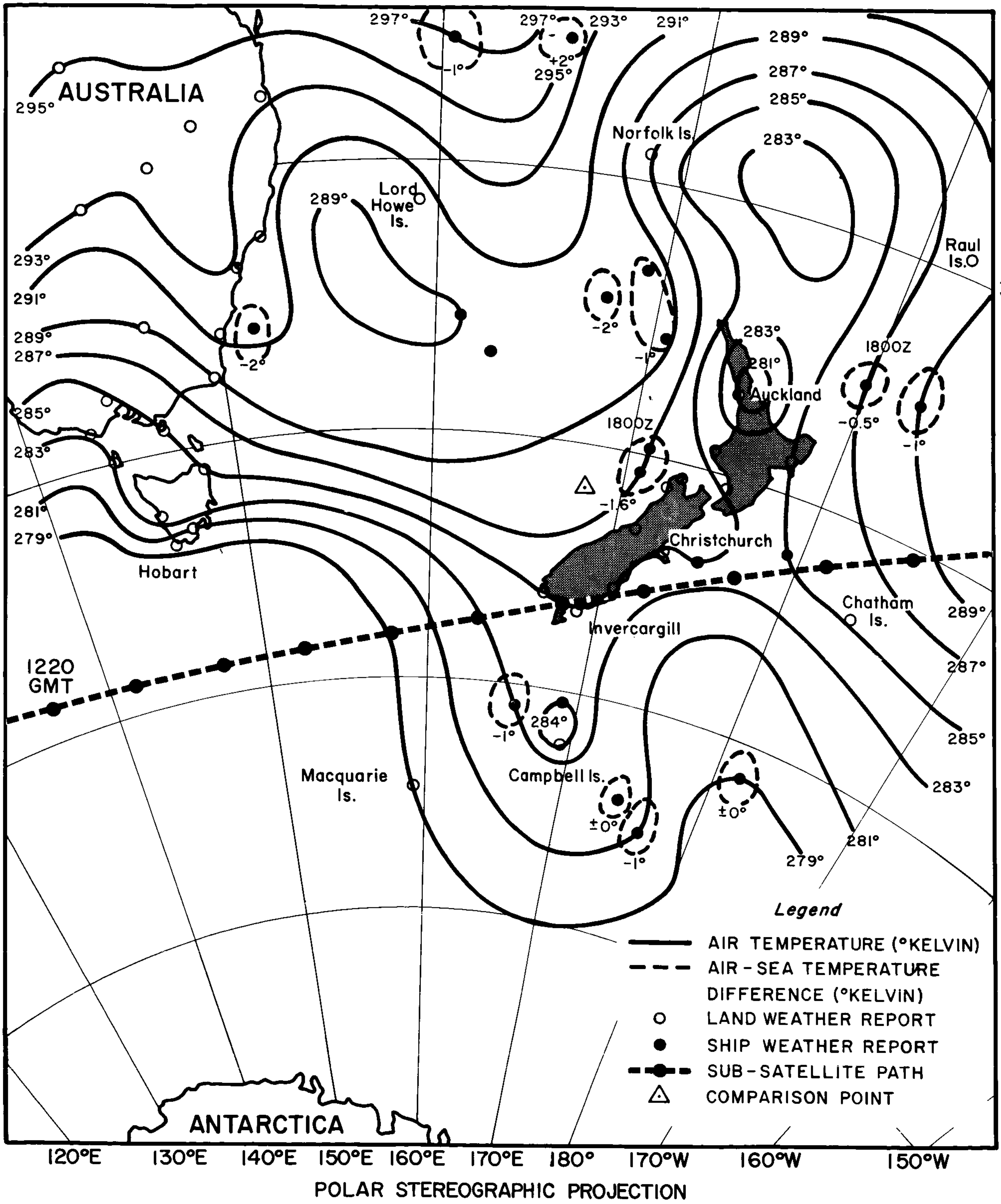
POLAR STEREOGRAPHIC PROJECTION

Figure 8 - Radiation Maps from the TIROS II 5-Channel Scanning Radiometer; Channel 4, Orbit O, 23 November 1960; 1220-1230 GMT, Orbit O.



POLAR STEREOGRAPHIC PROJECTION

Figure 9 - Radiation Map from the TIROS II 5-Channel Scanning Radiometer; Channel 1, Orbit O, 23 November 1960; 1220-1230 GMT, Orbit O.



AUSTRALIA
ANTARCTICA
Lord Howe Is.
Norfolk Is.
Raul Is.
Auckland
Christchurch
Invercargill
Chatham Is.
Hobart
Macquarie Is.
Campbell Is.
1220 GMT
1800Z
1800Z
297°
297°
293°
291°
289°
287°
285°
283°
295°
295°
293°
291°
289°
287°
285°
283°
281°
279°
289°
283°
281°
284°
289°
287°
285°
283°
281°
279°
-1°
+2°
-2°
-2°
-1°
-1.6°
-0.5°
-1°
-1°
±0°
-1°
±0°
30°S
40°S
50°S
120°E
130°E
140°E
150°E
160°E
170°E
180°
170°W
160°W
150°W
POLAR STEREOGRAPHIC PROJECTION
Legend
AIR TEMPERATURE (°KELVIN)
AIR - SEA TEMPERATURE DIFFERENCE (°KELVIN)
LAND WEATHER REPORT
SHIP WEATHER REPORT
SUB-SATELLITE PATH
COMPARISON POINT

Figure 10 - Surface Air Temperature and Sea Water Temperature Chart for the New Zealand Area, 1200 GMT, 23 November 1960.

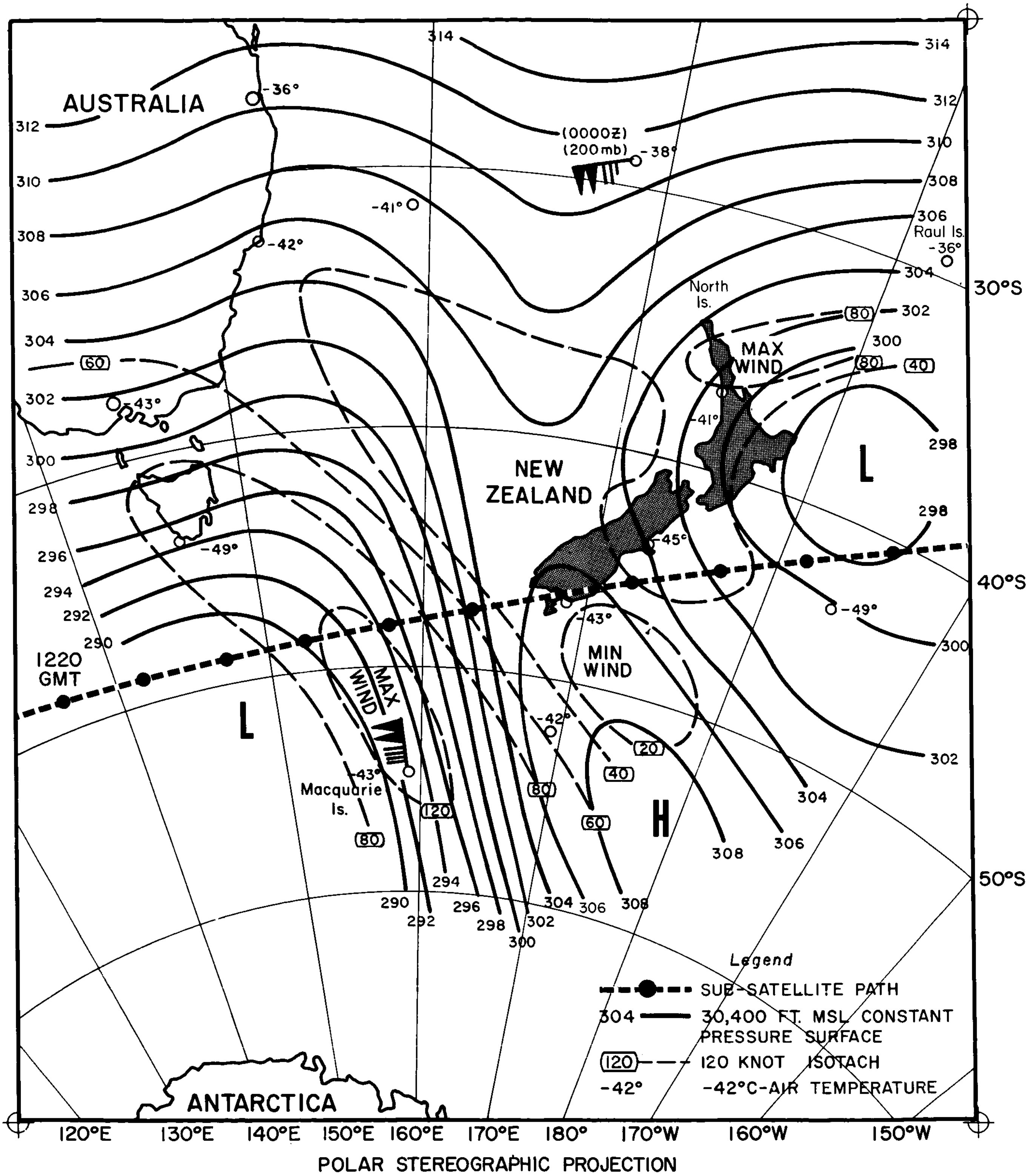
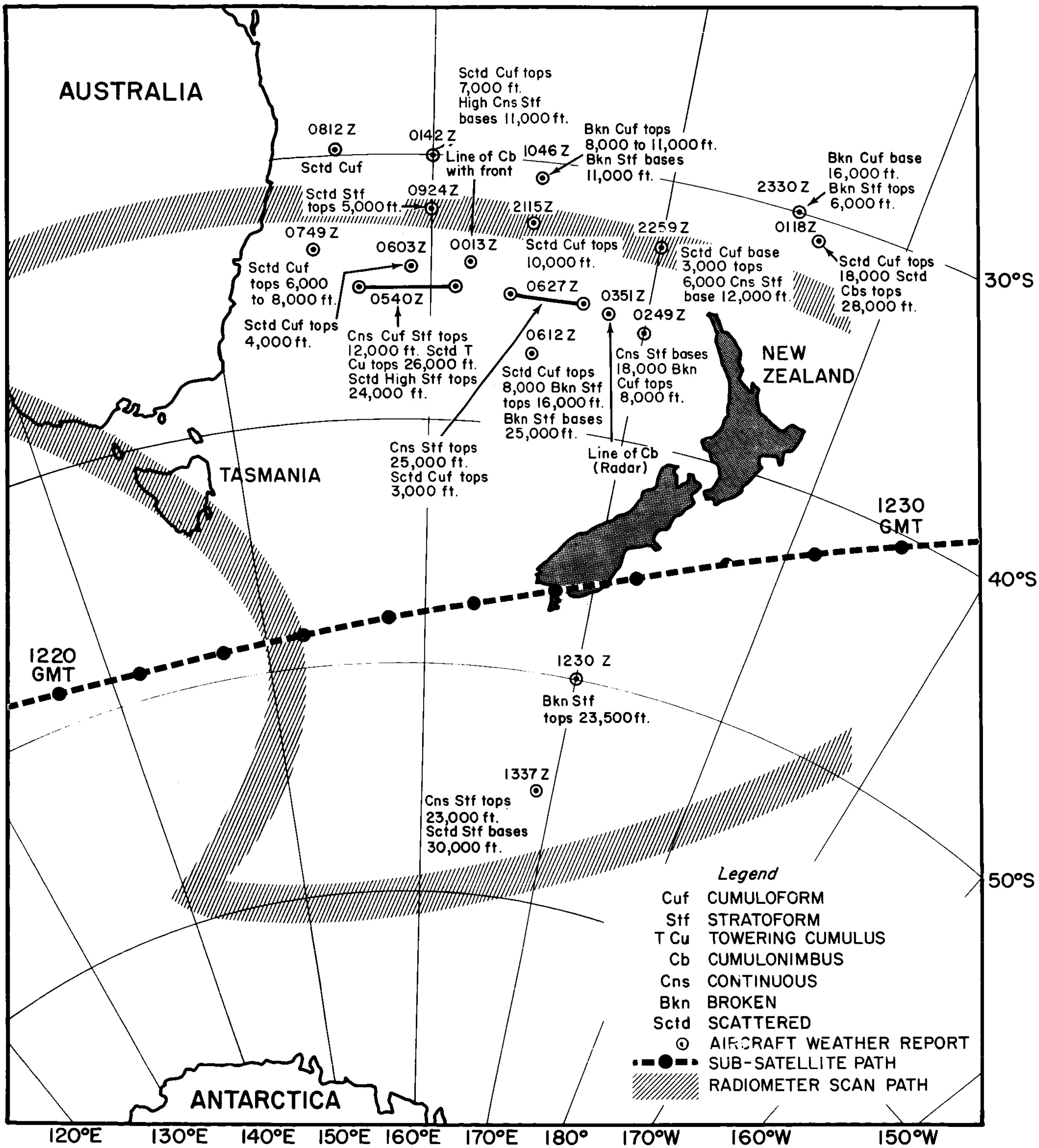
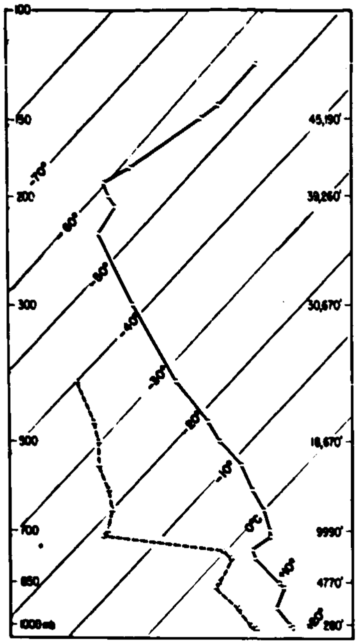

AUSTRALIA
NEW ZEALAND
North Is.
Raul Is.
MAX WIND
MIN WIND
Macquarie Is.
ANTARCTICA
(0000Z)
(200mb)
1220 GMT
30°S
40°S
50°S
Legend
SUB-SATELLITE PATH
304 30,400 FT. MSL CONSTANT PRESSURE SURFACE
120 120 KNOT ISOTACH
-42° -42°C-AIR TEMPERATURE
120°E 130°E 140°E 150°E 160°E 170°E 180° 170°W 160°W 150°W
POLAR STEREOGRAPHIC PROJECTION

Figure 11 - 300 mb. Constant Pressure Chart, 0000 GMT, 23 November 1960.

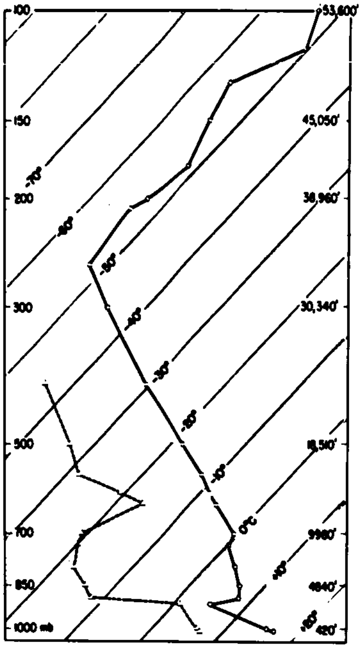


POLAR STEREOGRAPHIC PROJECTION

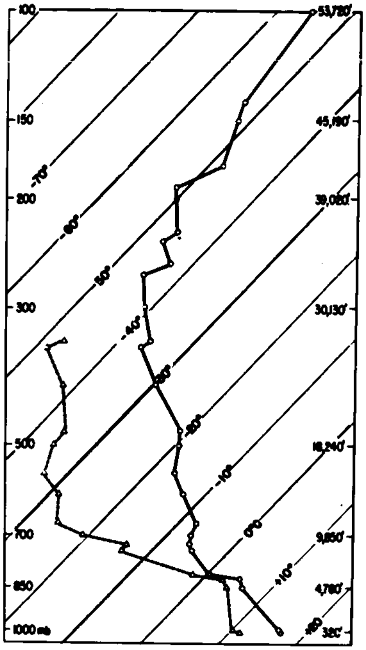
Figure 12 - Aircraft Weather Reports 0013-2330 GMT, 23 November 1960.



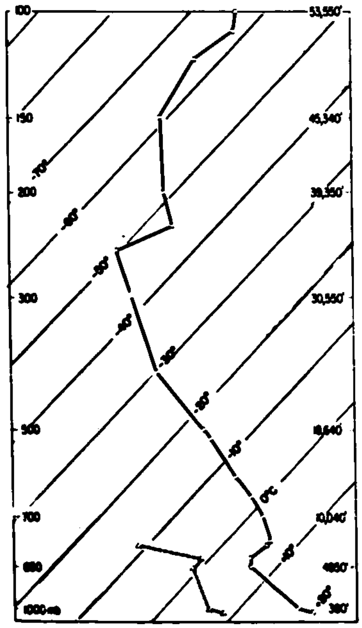
INVERCARGILL (N.Z.)



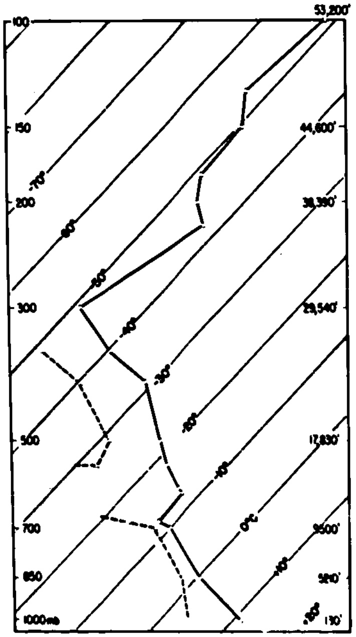
CHRISTCHURCH (N.Z.)



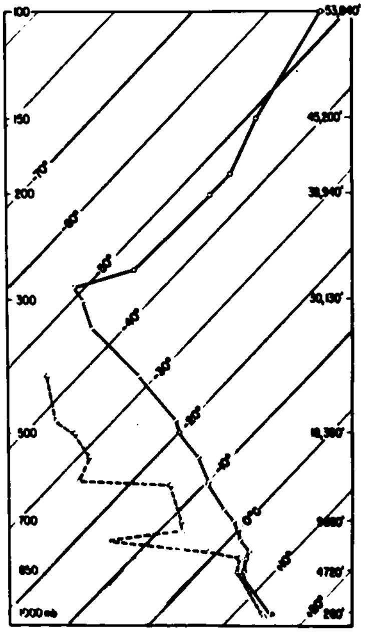
AUCKLAND (N.Z.)



WILLIAMTOWN (AUS.)



HOBART (TAS.)

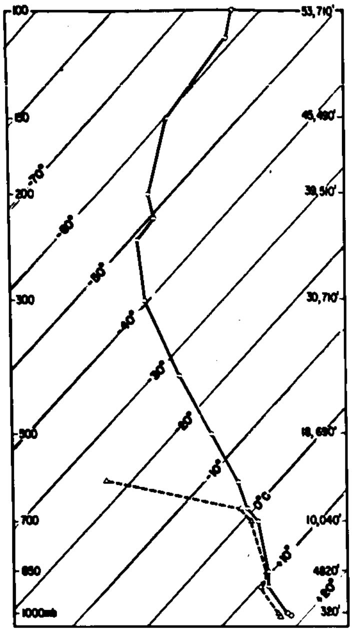


CHATHAM ISLAND (N.Z.)

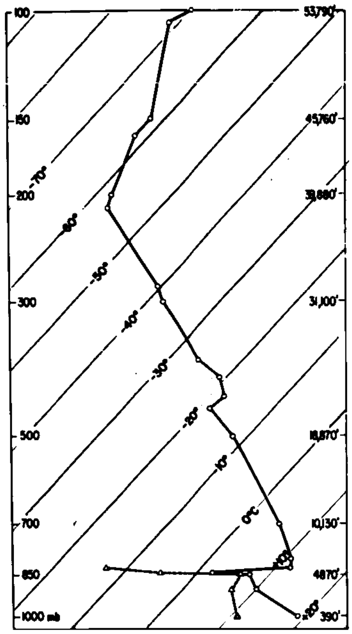
RADIOSONDE DATA

0000 GMT 23 NOV. 1960

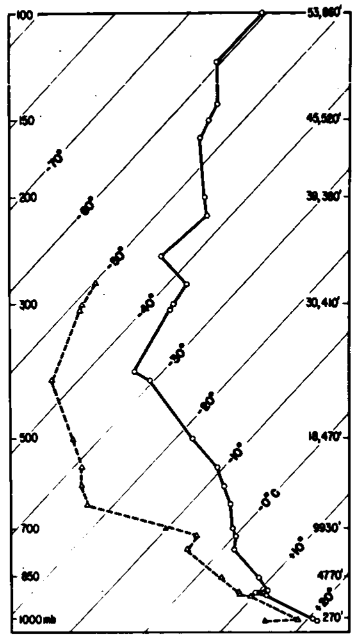
Figure 13 - Radiosonde Soundings, 0000 GMT, 23 November 1960. The solid line shows temperature distribution; the dashed line, dewpoint distribution.



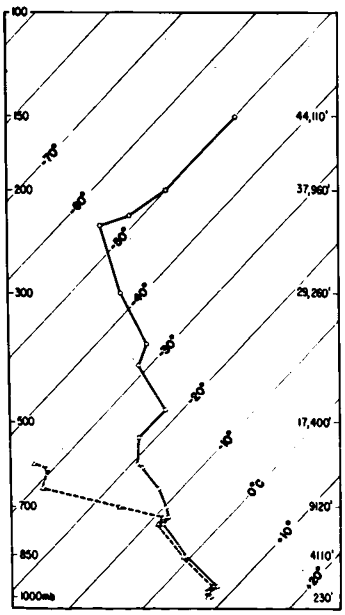
LORD HOWE ISLAND (AUS.)



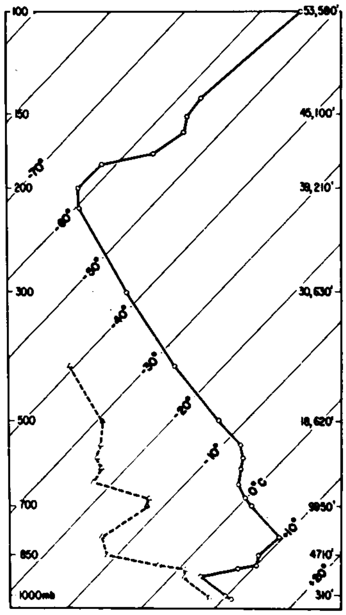
NORFOLK ISLAND (AUS.)



RAOUL ISLAND (N.Z.)



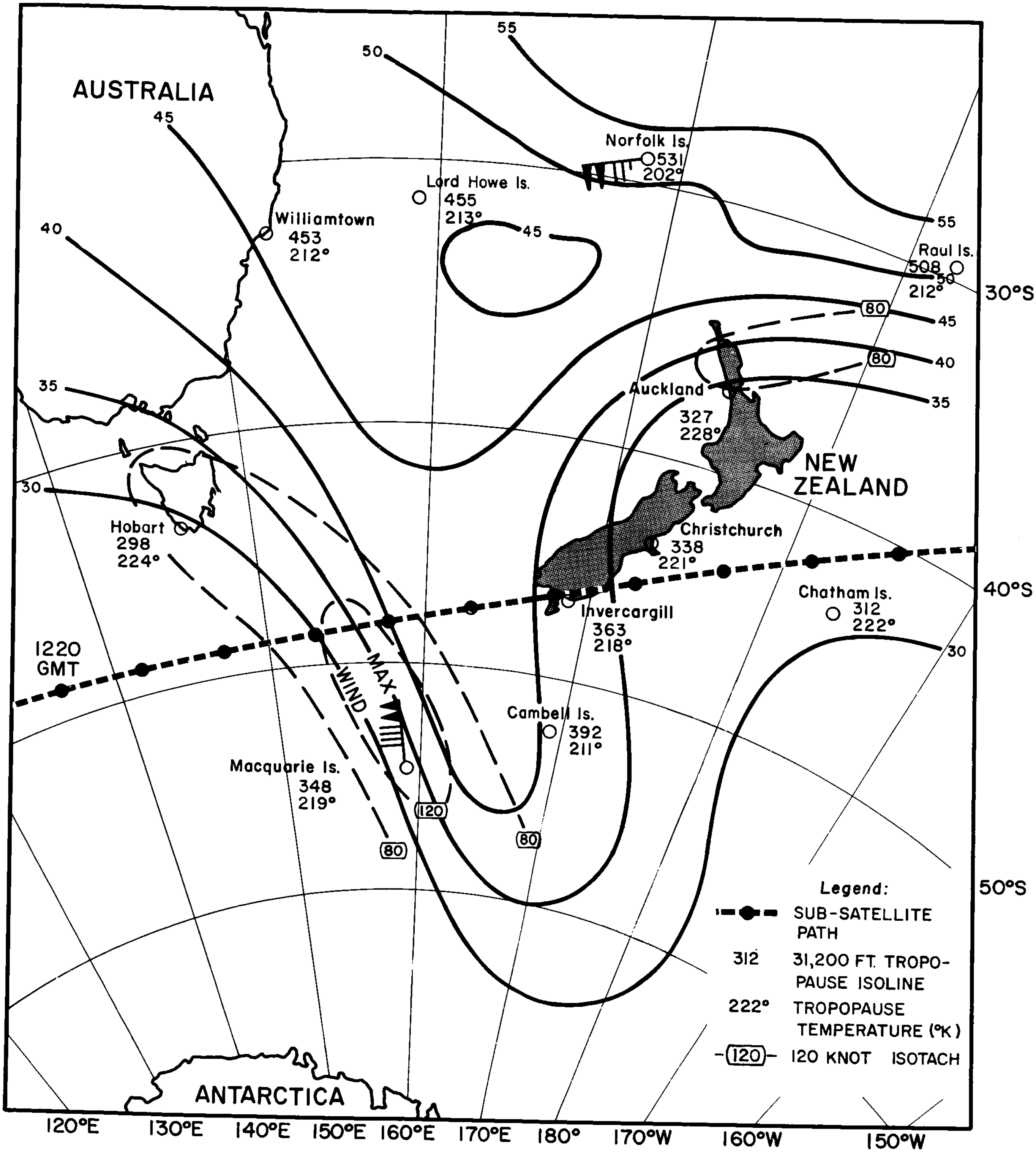
MACQUARIE ISLAND (AUS)



CAMPBELL ISLAND (N.Z.)

RADIOSONDE DATA
0000 GMT 23 NOV. 1960

Figure 14 - Radiosonde Soundings, 0000 GMT, 23 November 1960. The solid line shows temperature distribution; the dashed line, dewpoint distribution.



POLAR STEREOGRAPHIC PROJECTION

Figure 15 - Tropopause Height Chart, 0000 GMT, 23 November 1960.